Benefit Cost Analysis Memorandum

Growing Rural Economy and Agriculture through Transportation & Technology Enhancement or Replacement in North Carolina (GREATTER-NC)

2018 BUILD Grant Application

Prepared for NCDOT by AECOM

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Exhibits

Executive Summary

A benefit-cost analysis (BCA) was conducted for the Growing Rural Economy and Agriculture through Transportation & Technology Enhancement or Replacement in North Carolina (GREATTER-NC) Project to support the grant application of the North Carolina Department of Transportation for the USDOT's 2018 Better Utilizing Investments to Leverage Development (BUILD) program. There are 77 bridges comprising the project as a whole, and because each bridge has independent utility, individual BCAs were estimated for each. This analysis was conducted in accordance with the 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs. Capital outlays are scheduled to begin in 2019 for the first bridges and they are scheduled to begin operations that same year. The last bridge is scheduled for completion in 2023. All values are in 2017 dollars discounted to 2018, and cover a 30-year analysis period.

Exhibit 1 presents the Impact Matrix, which describes the baseline, the Project as a whole, and the estimated results.

Exhibit 1 – Impact Matrix

Current Status/Baseline & Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts	Affected Population	Economic Benefit (Net Present Values, $2017 M)		Page Reference in BCA
				Discounted at 7%	Discounted at 3%	
Fifty-eight (58) of the 77 Project bridges are structurally deficient or functionally obsolete, and are scheduled for replacement within the next STIP cycle. Nineteen (19) of the bridges are posted due to weight restrictions with the result that the large or heavy vehicles typically used in agriculture cannot use the structure. The restrictions result in detours or partial loading; both practices raise production costs and decrease farm incomes.	The Project would replace 77 rural bridges, bringing them up to a state of good repair and allowing for all vehicles to use them, reducing VMT and travel times in the region. In addition, adjacent farms will save some operating expenses from improved efficiencies in the transportation network, and the bridges will be safer. The reduced VMT results in travel cost savings for autos, operating cost savings for trucks, emissions savings, safety improvements and crash reductions, and residual value.	Safety:				
		Reduced Roadway Fatalities and Crashes	Drivers who reduce VMT after Project opening	$9.1	$25.3	11
		Safety Improvements at Bridges	Drivers and property owners near the Project bridges	$6.1	$10.7	13
		State of Good Repair:				
		Roadway Maintenance Savings	NCDOT Taxpayers	$1.2	$2.2	13
		Environmental Protection:				
		Emissions Savings	General public	$12.6	$22.3	15
		Economic Competitiveness:				
		Travel Time Savings	Drivers who reduce VMT after Project opening	-$21.4	-$23.4	14
		Auto Travel Cost Savings	Drivers who reduce VMT after Project opening	-$18.8	-$22.0	14
		Residual Savings	NCDOT Taxpayers	$5.7	$18.9	14
		Truck Operating Savings	Freight operators Shippers Customers	$145.8	$253.3	14
		Quality of Life:				
		Agricultural Access	Farms in the vicinity of Project bridges	$78.4	$130.0	15

Exhibit 2 summarizes long term outcomes of the Project. Taken in total, the Project provides $231.8 million in benefits—reduced roadway fatalities and crashes, roadway maintenance savings, travel time savings, congestion savings, travel cost savings, residual savings, freight benefits, and emissions savings—over the analysis period, using a 7 percent discount rate. Compared to a similarly discounted cost estimate, the Benefit-Cost Ratio for the Project is 1.18, a solid return on this critical investment for the region. This ratio rises to 1.80 when benefits and costs are discounted at 3 percent. The net benefits of the Project are $128.8 million using a 7 percent discount rate and $328.4 million using a 3 percent discount rate.

Exhibit 2 – Costs and Key Benefits Delivered by Long Term Outcomes (2021 – 2041)

Total Project	7% Discount Rate	3% Discount Rate
Costs (2017 $M)		
Capital Cost	$102.9	$110.8
Total Costs	*$102.9*	*$110.8*
Benefits (2017 $M)		
Safety Benefits		
Reduced Roadway Fatalities and Crashes	$9.1	$25.3
Safety Improvements at Bridges	$6.1	$10.7
Sub-Total	$15.3	$36.0
State of Good Repair Benefits		
Roadway Maintenance Savings	$1.2	$2.2
Sub-Total	$1.2	$2.2
Economic Competitiveness Benefits		
Travel Time Savings	-$21.4	-$23.4
Auto Travel Cost Savings	-$18.8	-$22.0
Residual Savings	$5.7	$18.9
Truck Operating Savings	$145.8	$253.3
Sub-Total	*$111.4*	*$226.8*
Environmental Protection		
Emissions Savings	$12.6	$22.3
Sub-Total	$12.6	$22.3
Quality of Life		
Agricultural Access	$78.4	$130.0
Sub-Total	$78.4	$130.0
Net Operating & Maintenance Costs	$12.9	$21.8
Total Benefits	*$231.8*	*$439.1*
Outcome		
Net Benefits (2017 $M)	$128.8	$328.4
Benefit-Cost Ratio	**2.25**	**3.96**

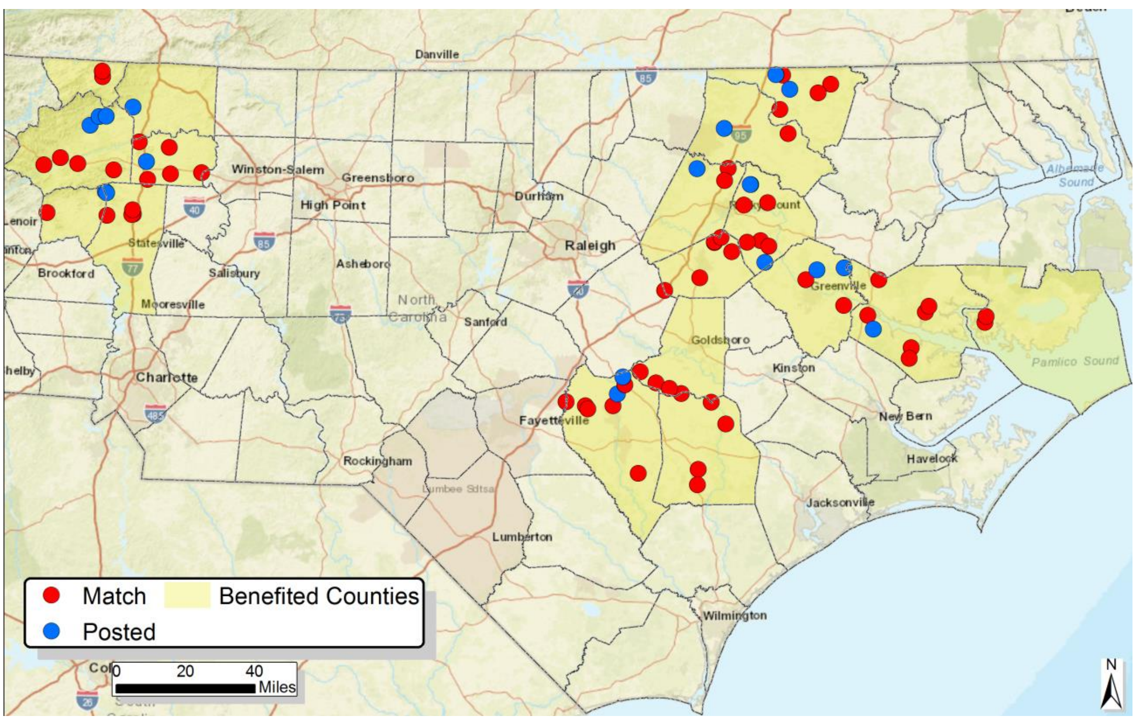
1. Introduction

The Growing Rural Economy and Agriculture through Transportation & Technology Enhancement or Replacement in North Carolina Project ("GREATTER-NC" or the "Project" hereafter) was developed through an innovative partnership among North Carolina's Departments of Transportation ("NCDOT" hereafter), Agriculture & Consumer Services, Commerce, and Information Technology, and the state's private technology sector. The Project will replace 77 rural bridges located in 17 of the most rural and economically depressed counties across the state, potentially adding broadband capability to some of the structures as they are replaced. The Project directly addresses the dual challenge of improving physical and digital connectivity in North Carolina's rural communities.

The Project bridges were selected according to three criteria: 1) whether the bridge's performance constrained mobility; 2) whether the bridge was located in a critical area for agricultural production; and 3) whether the bridges had weight restrictions and limited funding options.

The following 17 North Carolina counties contain one or more of the GREATTER-NC Project Bridges as identified in parenthesis. Attachment A to this application lists each of the 77 bridges by its Structure ID number and provides the geospatial (latitude and longitude) coordinates. Figure 3 illustrates the location of each Project bridge, indicating its status as a Match Bridge (one of the 58 bridges currently programmed with state dollars) or a Posted Bridge (one of the 19 bridges with compromised performance but ineligible for state funds). The Partnership section of this Narrative provides information about each County.

Exhibit 3 – Location of the Bridges in North Carolina



1. Alexander (1)
2. Alleghany (2)
3. Beaufort (7)
4. Duplin (4)
5. Edgecombe (8)
6. Halifax (2)
7. Hyde (2)
8. Iredell (6)
9. Nash (3)
10. Northampton (6)
11. Pitt (4)
12. Sampson (8)
13. Surry (1)
14. Wayne (4)
15. Wilkes (7)
16. Wilson (6)
17. Yadkin (6)

The GREATTER-NC Project addresses multiple criteria in the BUILD Grant notice. These include: Safety, Economic competitiveness, Quality of life, State of good repair, Environmental Protection, Innovation, and Partnership. In some cases, the expected GREATTER-NC Project outcomes apply to more than one of the benefit categories identified above. For example, the GREATTER-NC Project's potential broadband applications are described under the Innovation category, but enhanced broadband would also improve the quality of life for rural residents. Where this overlap occurs, the impact is described under the main category and referenced in the second.

- ***Safety***: The Project improves safety in several ways. First, in instances where the existing bridge was built decades ago, the new bridge and approach will be designed for modern standards and vehicles, reducing the potential for fatalities, injuries and crash costs. Second, once the bridge is replaced and able to accommodate all types of vehicles, detours will be eliminated, reducing vehicle miles traveled (VMT) and the chance of a crash. Finally, each of the replacement bridges will be built higher, reducing the likelihood of being flooded out and unavailable for use. The BCA estimates the value of the safer bridge design and the reduction in VMT. Data are not available to describe the value of a more reliable bridge during storm or flood events, so the benefit is noted here qualitatively, as instructed by the program guidance and consistent with BCA best practice.
- ***Economic Competitiveness***: Four types of economic competitiveness benefits are estimated as part of the benefit cost analysis. With the elimination of detours, travelers save time and avoid the cost of the extra VMT needed to make the detour. Trucks will save operating cost as well. As these bridges have a long useful life that exceeds the 30-year analysis period applied in the BCA, a residual value is estimated as well.

  The increased availability of broadband in rural areas is an additional factor supporting economic competitiveness. As the Project team did not have sufficient data to estimate how the broadband would be adopted and used over time, an economic estimate was not developed for inclusion in the BCA. The literature, however, suggests that the relationship between broadband adoption and rural growth is positive and significant. For example, Whitacre, et al concludes that "Results suggest that high levels of broadband adoption in rural areas do causally (and positively) impact income growth between 2001 and 2010 as well as (negatively) influence unemployment growth. Similarly, low levels of broadband adoption in rural areas lead to declines in the number of firms and total employment numbers in the county."
- ***Quality of Life***: The Project benefits Quality of Life in several ways. First, the low posted weight limit of the bridge causes a daily inconvenience to travelers including school buses. Second, in instances where broadband is placed on the bridge, the improved connectivity, assuming service is provided, benefits rural households in the vicinity that tap into the service. And third, the ability to move large farm equipment among fields allows agricultural producers to conduct their work more efficiently. The AADT counts for the bridges likely omit counts of tractors and other farm machinery that must divert and find another route when moving from field to field during planting, disking or harvest season. This analysis provides a conservative estimate of the value of improved agricultural production efficiency in the vicinity of the bridges. The improved efficiency allows farmers to be more profitable, supporting rural incomes.

- ***State of Good Repair***: Once the Posted bridges are replaced and able to accommodate all types and weights of typical vehicles in use, the need to detour around the bridge will be eliminated, reducing truck and bus VMT and roadway wear and tear.
- ***Environmental Protection***: Once the Posted bridges are replaced and able to accommodate all types and weights of typical vehicles in use, the need to detour around the bridge will be eliminated as noted above, reducing emissions.
- ***Innovation***: The introduction of broadband capability to the bridge structures supports broadband adoption in rural areas in two ways. First, it can be directly tied into dark fiber, or an unused optical fiber available for lease, and help connect the first mile provider to the last mile consumer. In some cases, just making the connection over a water crossing reduces the up-front cost of providing service - a barrier to entry in rural markets - and helps private providers enter rural markets. When these barriers can be overcome, there is evidence that the economic return on investment can be high. Recent research presented at the 2018 Economic Returns to Rural Infrastructure Investment Workshop found that a $1 increase in zip code per capita broadband loan results in about a $1.08 increase in annual payroll per worker, implying a rate of return of about 8 percent.

  While the study above provides a macro assessment of the connection between broadband and rural economic prosperity, the BUILD grant program is transportation-focused. One of the big opportunities of the Project is the synergy with the CCX. At present, the CCX does not have broadband service, although there are fiber corridors in the vicinity. Through this project and the addition of broadband capability to nearby bridge projects, the CCX will gain a reliable source of broadband service. NCDOT's partnership with NCDIT and their broadband grant program may also be beneficial in securing funding for expanding broadband service in the area. Not yet under construction, the CCX is nonetheless beginning to attract business to the surrounding area, gradually attracting firms to create a freight logistics hub. The broadband capability will permit the firms in the hub to access foreign markets, to coordinate with the CCX, and as congestion grows, to implement ITS solutions to manage congestion.

  In addition to providing the opportunity to connect rural areas through broadband, the Project plans to employ innovative project delivery methods by bundling the Match and Posted bridges in groups. This approach allows the Department to advance construction of the low-volume posted bridges.
- ***Partnership***: GREATTER-NC was developed through an innovative partnership among NCDOT, Agriculture & Consumer Services, Commerce, and Information Technology, and the state's private technology sector. The GREATTER-NC Project has broad-based, multi-jurisdictional support from the community, stakeholders and elected officials as evidenced from the Letters of Support provided in the Supplementary Materials submitted with the application narrative and on the website (https://connect.ncdot.gov/resources/GREATTER-Rural-Bridge-Program).

2. Benefit Analysis Framework

The benefits analysis was conducted using the Benefit-Cost Analysis Guidance for Discretionary Grant Programs document as a guide for preferred methods and monetized values. The parameters of the benefits analysis follow the protocols set by the Office of Management and Budget (OMB) Circular A-94 as well as the recommended benefit quantification methods by the USDOT, the United States Army Corps of Engineers, the Federal Emergency Management Agency, and U.S. Department of Agriculture, Forest Service. Generally, standard factors and values accepted by federal agencies were used for the benefits calculation except in cases where more Project-specific values or prices were available. In all such cases, modifications are noted and references are provided for data sources. The analysis follows a conservative estimation of the benefits and assesses some of the benefits qualitatively. By adhering to a strict standard of what could be included in the benefits analysis, actual total benefits may be greater than depicted in the results.

The baseline assumes that the Project would not be built and current conditions and operations would continue in the project area. Under the baseline, the purpose of and need for the Project would not be met and would generally be limited to the operation and maintenance of existing infrastructure. The Project was compared to the baseline to identify benefits and costs.

A custom model was developed to estimate the future benefits for the Project. Benefits were estimated over a 30-year period of analysis beginning when construction ends and concluding after 30 full years of operations. Each project schedule varies, but for the group of 77 projects, the construction period is from 2018 through 2022, and operations range from 2019 through 2052 with partial years included as needed. The base year is 2018 and all values were discounted to the base year.

The benefits are expressed in constant 2017 dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The gross domestic product chained price index from the OMB was used to adjust past cost estimates or price values into 2017dollar terms (OMB, 2018).

The use of constant dollar values requires the use of a real discount rate for discounting to the present value. Projects expecting to use federal funding are required to use a 7 percent discount rate. A 3 percent discount rate was also used.

3. Analysis Assumptions

A list of assumptions for the Project is provided in the BCA workbook (see Inputs tab in the file BCA.xlsx) as well as in Exhibit 4.

Exhibit 4 – BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2018 BCA Guidance for Discretionary Grant Programs
Discount Rate	3%	2018 BCA Guidance for Discretionary Grant Programs
Deflator	See "Deflator" Sheet	https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/hist10z1.xls
Dollar year	2017	
Discount year	2018	
Annualization factor	365	
Vehicle occupancy	1.39	2018 BCA Guidance for Discretionary Grant Programs
AADT annual growth	1%	NCDOT
Annual existing bridge O&M, up to 44 years, (2017$)	$8,000	NCDOT
Annual existing bridge O&M, 45-65 years, (2017$)	$12,000	NCDOT
Annual existing bridge O&M, 66-89 years, (2017$)	$16,000	NCDOT
Annual existing bridge O&M, greater than 90 years, (2017$)	$25,000	NCDOT
State of Good Repair		
Roadway Maintenance Cost per Mile, Rural Interstate (2017$) - Auto	$0.000	Source: FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13, Adjusted by GDP Deflator
Roadway Maintenance Cost per Mile, Rural Interstate (2017$) - 40 kip truck	$0.014	Source: FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13, Adjusted by GDP Deflator
Share of Construction costs that are for bridge structure	75%	Engineering judgement

Economic Competitiveness		
Vehicle Maintenance Cost per Mile, Auto (Gas, maintenance, tires, and depreciation) (2017$/Mile)	$0.39	2018 BCA Guidance for Discretionary Grant Programs
Average Marginal Costs per Mile, 2017$ (includes value of driver's time)	$1.62	Table 8 ATRI Operational Cost of Trucking 2017, Adjusted by GDP Deflator
Value of Time (2017$), private vehicle travel time per person hour, all purposes	$14.20	2018 BCA Guidance for Discretionary Grant Programs
Value of Time (2017$), truck driver per hour	$28.60	2018 BCA Guidance for Discretionary Grant Programs
Environmental Sustainability		
VOC Value of Emissions (2017$) per short ton	$1,905	2018 BCA Guidance for Discretionary Grant Programs
NOx Value of Emissions (2017$) per short ton	$7,508	2018 BCA Guidance for Discretionary Grant Programs
PM Value of Emissions (2017$) per short ton	$343,442	2018 BCA Guidance for Discretionary Grant Programs
SO2 Value of Emissions (2017$) per short ton	$44,373	2018 BCA Guidance for Discretionary Grant Programs
Passenger Car Emission Rates per Mile, VOC, 2013-2024	0.6	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, NOx, 2013-2024	0.91	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, PM25, 2013-2024	0.01	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, CO2, 2013-2024	532	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, VOC, 2025-2034	0.27	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, NOx, 2025-2034	0.28	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, PM25, 2025-2034	0.01	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, CO2, 2025-2034	434	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, VOC, 2035-	0.21	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, NOx, 2035-	0.2	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, PM25, 2035-	0.01	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Passenger Car Emission Rates per Mile, CO2, 2035-	397	http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf
Conversion rate for Metric tons to Short Tons	1.1015	2018 BCA Guidance for Discretionary Grant Programs
Truck Emissions Rate g per mile VOC (average of gasoline and diesel)	1.0165	EPA 420-F-08-027, Average In-Use Emissions from Heavy-Duty Trucks, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVY6.TXT

Truck Emissions Rate g per mile NOx (average of gasoline and diesel)	5.7635	EPA 420-F-08-027, Average In-Use Emissions from Heavy-Duty Trucks, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVY6.TXT
Truck Emissions Rate g per mile PM2.5 (average of gasoline and diesel)	0.123	EPA 420-F-08-027, Average In-Use Emissions from Heavy-Duty Trucks, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVY6.TXT
Truck Emissions Rate g per mile PM10 (average of gasoline and diesel)	0.135	EPA 420-F-08-027, Average In-Use Emissions from Heavy-Duty Trucks, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVY6.TXT
Quality of Life		
Safety		
AIS 0 (2017$) per vehicle	$4,327	2018 BCA Guidance for Discretionary Grant Programs
AIS 1 (2017$)	$28,800	2018 BCA Guidance for Discretionary Grant Programs
AIS 2 (2017$)	$451,200	2018 BCA Guidance for Discretionary Grant Programs
AIS 3 (2017$)	$1,008,000	2018 BCA Guidance for Discretionary Grant Programs
AIS 4 (2017$)	$2,553,600	2018 BCA Guidance for Discretionary Grant Programs
AIS 5 (2017$)	$5,692,800	2018 BCA Guidance for Discretionary Grant Programs
AIS 6 (2017$)	$9,600,000	2018 BCA Guidance for Discretionary Grant Programs
Crash Modification Factor	22%	NCDOT
Injury Modification Factor	22%	NCDOT
O- No Injury (2017$)	$3,200	2018 BCA Guidance for Discretionary Grant Programs
C - Possible Injury (2017$)	$63,900	2018 BCA Guidance for Discretionary Grant Programs
B - Non-incapacitating (2017$)	$125,000	2018 BCA Guidance for Discretionary Grant Programs
A - Incapacitating (2017$)	$459,100	2018 BCA Guidance for Discretionary Grant Programs
K - Killed (2017$)	$9,600,000	2018 BCA Guidance for Discretionary Grant Programs
U - Injured (Severity Unknown) (2017$)	$174,000	2018 BCA Guidance for Discretionary Grant Programs
# Accidents Reported (Unknown if Injured) (2017$)	$132,200	2018 BCA Guidance for Discretionary Grant Programs

4. Benefits Methodology

The methodology used to estimate the benefits of the Project are described in the following sections. The benefits estimated in these sections apply to all bridges.

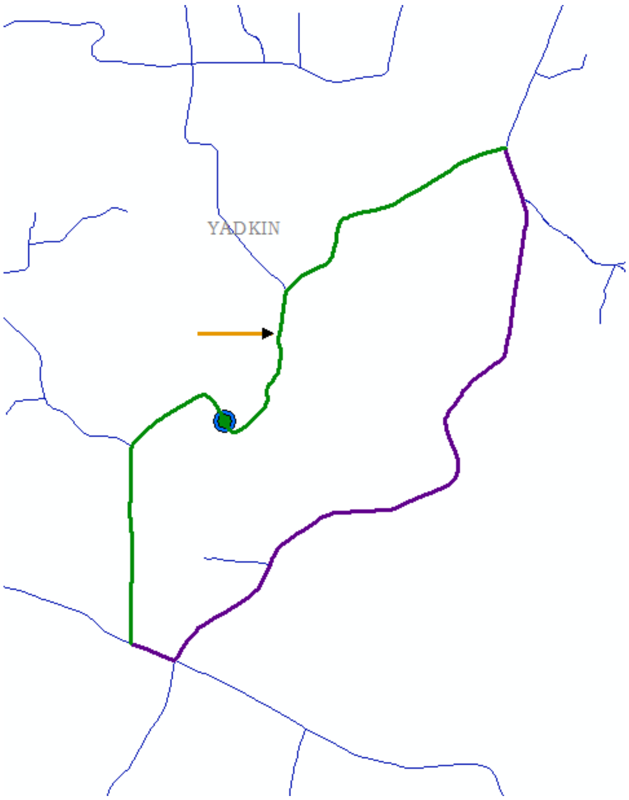
Safety

The Project would result in safety benefits by removing trips from the region’s roads and bringing the bridges up to current design standards. The methodologies for calculating this benefit are described in this section.

Reduced Roadway Fatalities and Crashes

The construction of the bridges results in temporary closure of the bridge and therefore forces all traffic to take a longer route. This longer route results in increased vehicle miles traveled for the duration of bridge closure. Offsetting the temporary increase in VMT for construction is the reduction in VMT once the bridges open. Under the baseline condition, trucks that are overweight of the posted bridge weight limit must divert around the bridge. The diversion mileage was estimated for each bridge using GIS for the shortest through-route. The diversion is conservative, as a truck that originates or is destined closer to the bridge location would take a longer detour than the average through traffic. See Exhibit 5 for an example of the routes estimated for each bridge. The blue dot is the bridge, and the green route is the through-route that a truck intends to travel, but because the bridge is posted, the truck must take the longer purple route. If the truck were traveling from the south to a farm, for example, at the orange arrow, the detour length would be longer than that used in the analysis. For that reason, the VMT estimates are conservative.

Exhibit 5 – Example Detour for Overweight Trucks



Source: NCDOT GIS

The annual average daily traffic (AADT) for each bridge was provided by NCDOT and the numbers of trucks that divert due to posted weight limits were estimated by NCDOT based on a ratio of existing AADT, truck percentages, and weight limits. Multiplying the number of trucks diverted daily by 365 to get annual traffic, and by the net diversion (purple mileage less green mileage) results in the annual VMT saved under the project. Multiplying the AADT by the bridge closure time provided by NCDOT and the net diversion mileage results in the additional VMT incurred during the construction period.

The rates of crashes that result in fatalities, injuries, and property damage are applied to the net annual VMT to derive the estimated crashes from the change in VMT. To ensure consistency between the types of crashes, the crash rates for fatalities, injuries, and property damage are the national average crash rates. These crash rates are shown in Exhibit 6.

Exhibit 6 - Crashes by Type per 100,000,000 VMT

Fatalities	1.133692236
Injured persons	78.93618107
Crashes	203.3926964

Source: 2015 BTS Motor Vehicle Safety Data Table 2-17, https://www.bts.gov/content/motor-vehicle-safety-data

These crash reduction factors were then converted to the Maximum Abbreviated Injury Score (MAIS) crash types in order to apply US DOT Guidance on the value of avoiding a crash. The conversion is based on the National Highway Safety and Traffic Administration (NHTSA) KABCO-AIS Conversion Table (July 2011) provided on page 12 of the TIGER Benefit-Cost Analysis Resource Guide (USDOT 2016),[1] for Injury (severity unknown), and No Injury crashes. KABCO refers to the letters used to designate five levels of crash severity used by police at a crash scene; AIS refers to the Abbreviated Injury Scale used by hospitals. These factors provide the probability that an injury will range from critical to minor to more accurately capture the total number of different types of injuries associated with the VMT avoided. Estimating the distribution of expected injury types is important because the economic cost of the injury increases as injury severity increases.

The total annual value for crash severity is based on USDOT guidance and the National Highway Safety Council estimates for the value of avoiding a crash. These estimates are applied to the number of crashes avoided to estimate the total value of crashes avoided from auto VMT avoided. Exhibit 4 provides the estimated cost of different types of crashes.

The total reduction in highway fatalities and crashes results in $9.1 million in benefits, discounted at 7 percent.

Safety Improvements at Bridges

In addition to the safety benefit from changes to VMT in the state, the replacement of the bridges results in safety benefits from bringing the bridges up to current design standards. On average, the bridges were constructed in 1958 and are therefore out of date and lacking the safety features and designs of today's bridges. Three improvements will be made to the new bridges: first, guard rail will be added and replaced up to AASHTO standard; second, the bridges will be widened from their current 24'-28' up to 28'-33'; and third, horizontal alignments will be altered up to 300 feet on each approach.

NCDOT estimated that a 22% reduction in crashes would occur at the bridges once replaced.[2] NCDOT provided crash data within 500 feet of the bridges over a five-year period. Data were provided for fatalities and injuries of type A, B, and C, and PDO and unknown crashes. The reduced fatalities, injuries, and property damage were valued based on USDOT guidance and are listed in Exhibit 4. ***The total safety improvements at bridges results in $6.1 million in benefits when discounted at 7 percent.***

In addition, the project bridges will be replaced at higher elevations, reducing the likelihood of wash-out and improving hydraulic conveyance. They are likely to reduce upstream flooding, possibly affecting open farm land and forest areas. These benefits were not able to be quantified for this analysis.

State of Good Repair

The Project would result in state of good repair benefits by removing auto trips from the region's roads. The methodology for calculating this benefit is described in this section.

Roadway Maintenance Savings

An increase in auto VMT during construction incurs additional roadway maintenance costs, such as painting and paving. The roadway maintenance cost savings is negligible per auto VMT on rural highways, as obtained from the FHWA Highway Cost Allocation Study. Like autos, trucks incur more VMT during construction but save VMT once the bridges are open; the FHWA Highway Cost Allocation Study values their roadway maintenance cost per mile at $0.014 for a 40-kip truck. Multiplying the auto and truck VMT by the maintenance costs per VMT results in state of good repair benefits. ***Roadway maintenance savings amount to $1.2 million, discounted at 7 percent.***

[1] Benefit-Cost Analysis (BCA) Resource Guide 2016, https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf
[2] NCDOT, An Analysis of the Traffic Safety Effects of Bridge Replacement on North Carolina Highways, 2002

Economic Competitiveness

The Project would produce economic benefits by allowing trucks to take a more direct route, resulting in travel time savings, auto travel cost savings, residual value, and truck operating cost savings. The methodologies for calculating these benefits are described in this section.

Travel Time Savings

Because autos must travel longer routes during the construction period, they incur travel time delays. Assuming a 35 mile per hour travel speed on both the through-route and the detour route, the average travel time loss was estimated for the annual traffic volumes. Multiplying the annual hours lost by the average vehicle occupancy (1.39)[3] and the personal value of time ($14.20 in 2017 dollars), as found in Exhibit 4, yields the total travel time savings. ***The total travel time savings for the Project amounts to -$21.4 million discounted at 7 percent.***

Auto Travel Cost Savings

The longer auto trips during construction also result in negative travel cost savings. Travel cost savings was estimated using a cost savings per reduced auto VMT of $0.39, which is based on the vehicle maintenance cost per mile provided by AAA and recommended by guidance.[4] The marginal savings includes gas, maintenance, and tires. These cost savings for trucks are estimated as part of the Truck Operating Savings in order to avoid double-counting. ***Auto travel cost savings amount to -$18.8 million discounted at 7 percent.***

Residual Value

Construction of the new bridges results in residual value after the end of the 30-year analysis period, because the useful life of the bridge is 75 years.[5] Right of way does not depreciate, so the full value of the right of way acquired for the Project was also included in the residual analysis. It was assumed that 75 percent of the capital costs for construction are for bridge infrastructure. The remaining value of the bridge and right of way acquired was summed and discounted from the last year of the 30-year analysis period. ***The value of the remaining useful life for the Project discounted at 7 percent is $5.7 million.***

Truck Operating Savings

Based on the additional truck VMT incurred during construction and the long-term truck VMT savings from avoiding detours when the bridges' posted weights increase, the net truck operating savings is calculated. The savings per mile of $1.62 in 2017 dollars is the average marginal cost per mile for truck operations from the American Trucking Research Institute. This cost includes both vehicle-based costs and driver-based costs. ***The total truck operating savings for the Project amounts to $145.8 million discounted at 7 percent.***

[3] 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2018.pdf

[4] Source: AAA, Your Driving Costs, 2017

[5] Source: USDOT Bridge Preservation guide, Maintaining a State of Good Repair Using Cost Effective Investment Strategies, August 2011, page 2, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiv-8XR8cLLAhVV5WMKHYZ6Ap8QFggcMAA&url=http%3A%2F%2Fwww.fhwa.dot.gov%2Fbridge%2Fpreservation%2Fguide%2Fguide.pdf&usg=AFQjCNEf26d_7T9a9n7jxVGGtwyGvq2zQg&sig2=Z8jY2-M9fT0zre_vXvSplg&bvm=bv.116954456,d.cGc

Environmental Protection

The Project would result in net environmental protection benefits by temporarily increasing auto and truck VMT during construction but reducing truck VMT in the long-term. The methodology for calculating this net result is described in this section.

Emissions Savings

The increase in auto and truck VMT will result in a temporary increase in emissions during the construction period, but the reduction in truck VMT after the bridges open results in overall emissions savings for the long-term. The two are netted in this analysis.

The emissions increases for autos were estimated using emissions rates from USDOT guidance for volatile organic compounds (VOC), nitrogen oxides (NOx), and particulate matter ($PM_{2.5}$).[6] The rates for autos are shown in Exhibit 4 and vary over time as vehicle efficiencies improve. The incremental increase in truck emissions resulting from increases in VMT during construction were netted with the truck VMT savings in the long-term when trucks no longer have to take longer routes around posted bridges. The emissions rates for trucks for VOC, NOx, $PM_{2.5}$, and PM_{10} are shown in Exhibit 4 and are constant over the analysis period.

The tons of emissions reduced were summed and monetized using the recommended value of emissions from 2018 USDOT guidance,[7] also shown in Exhibit 4. ***In total, the Project results in net emissions savings of $12.6 million when discounted at 7 percent.***

In addition to VOC, NOx, and PM reductions, carbon dioxide (CO_2) or greenhouse gas emissions would also be reduced. Because there is no official guidance on the value of CO_2 emissions reductions, these benefits were not quantified in the analysis.

Quality of Life

The ability to move large farm equipment among fields allows agricultural producers to conduct their work more efficiently. The improved efficiency allows farmers to be more profitable, supporting rural incomes. The methodology for quantifying this benefit is described in this section.

In addition, the installment of broadband for the Carolina Connector Intermodal Terminal (CCX) in Rocky Mount demonstrates a synergy and innovation of the project. Through this project and the addition of broadband capability to nearby bridge projects, the CCX will gain a reliable source of broadband service. Not yet under construction, the CCX is nonetheless beginning to attract business to the surrounding area, gradually attracting firms to create a freight logistics hub. The broadband capability will permit the firms in the hub to access foreign markets, to coordinate with the CCX, and as congestion grows, to implement ITS solutions to manage congestion. The value of this benefit was not quantitatively included in the BCA.

Agricultural Access

The replacement bridges benefit the farms that are nearby by allowing trucks to take more direct routes to and from markets and also allowing farm equipment and products to move around more efficiently within and between farms. The agricultural access benefit quantifies the increase in farm efficiency that can be realized with an improved transportation network. As found in the Soybean Checkoff funded analysis, "Farm to Market: A Soybean's Journey," 100 percent of the soybean deliveries from the farm to the elevator occur via truck, or to a much lesser extent, grain wagon. Eighty-five percent of deliveries from the

[6] USDOT, Federal Transit Administration, New and Small Starts Evaluation and Rating Process Final Policy Guidance, August 2013

[7] 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2018.pdf

elevator to the processor, rail loading facility, or barge loading facility occur via truck. Therefore, if trucking is inefficient, farmers will be inefficient, and profitability will decline."[8]

Based on 2012 county average total farm production expenses,[9] converted to 2017 dollars, a 1 percent reduction in expenses is assumed to be attributable to the bridge projects. It is assumed that each bridge replacement affects 3 percent of the farms in the county. Multiplying the average expense savings by the number of farms results in the total annual agriculture access benefits. The annual reduction in expenses was held constant throughout the analysis period. This improved efficiency allows farmers to be more profitable, supporting rural incomes. ***In total, the Project results in agricultural access benefits of $78.4 million when discounted at 7 percent.***

5. Costs

The Project has two cost components: the initial capital costs and ongoing operating and maintenance (O&M) costs. The components used in this analysis are described in this section.

Capital Costs

The capital costs for the Project include the costs for right of way, utilities, design, and construction. The capital costs are applied over the individual project construction periods, beginning in fall 2018 and ending in fall 2023. Capital costs were given in 2018 dollars and converted to 2017 dollars using the GDP deflator, resulting in a total cost of $119.1 million. It is estimated that the individual project costs are expended equally over the construction periods. The bridges range in cost between $348,000 and $8.3 million. ***The total capital costs for the Project discounted at 7 percent are $102.9 million.***

Annual Operating and Maintenance Costs

The Project requires annual and periodic O&M expenditures to maintain the new bridge, but the replacement bridge would result in O&M savings from the baseline. In the baseline, the cost to maintain the bridges was provided by NCDOT and is based on the bridge age, as shown in Exhibit 7.

Exhibit 7 – Annual O&M Costs for Existing Bridges by Age

Bridge Age	Annual O&M Cost
Up to 44 years	$8,000
45-65 years	$12,000
66-89 years	$16,000
>90 years	$25,000

Maintenance of the new bridges occurs only in years 10 and 16-30 at lower costs than the existing O&M costs, so many years result in O&M savings from the bridge replacement. ***The net O&M savings over the analysis period and discounting at 7 percent is $12.9 million.***

[8] American Soybean Association, "The Hard Cost of Bad Infrastructure," from Spring 2017 *American Soybean Magazine,* https://soygrowers.com/american-soybean-mag/hard-cost-bad-infrastructure/ Accessed 7/15/18
[9] 2012 North Carolina Agricultural Statistics, Crop * Livestock Cash Receipts by County, https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat/Section06.pdf

6. BCA Results

The analysis results in a total Project BCA ratio of nearly 2.25 when discounted at a rate of 7 percent, and increases to 3.96 when discounted at 3 percent.

Exhibit 8 displays a summary of the BCA results for the total Project and Exhibit 9 shows the results for each bridge individually.

Exhibit 8 – BCA Results

Total Project	7% Discount Rate	3% Discount Rate
Costs (2017 $M)		
Capital Cost	$102.9	$110.8
Total Costs	*$102.9*	*$110.8*
Benefits (2017 $M)		
Safety Benefits		
Reduced Roadway Fatalities and Crashes	$9.1	$25.3
Safety Improvements at Bridges	$6.1	$10.7
Sub-Total	$15.3	$36.0
State of Good Repair Benefits		
Roadway Maintenance Savings	$1.2	$2.2
Sub-Total	$1.2	$2.2
Economic Competitiveness Benefits		
Travel Time Savings	-$21.4	-$23.4
Auto Travel Cost Savings	-$18.8	-$22.0
Residual Savings	$5.7	$18.9
Truck Operating Savings	$145.8	$253.3
Sub-Total	*$111.4*	*$226.8*
Environmental Protection		
Emissions Savings	$12.6	$22.3
Sub-Total	$12.6	$22.3
Quality of Life		
Agricultural Access	$78.4	$130.0
Sub-Total	$78.4	$130.0
Net Operating & Maintenance Costs	$12.9	$21.8
Total Benefits	*$231.8*	*$439.1*
Outcome		
Net Present Value (2017 $M)	$128.8	$328.4
Benefit-Cost Ratio	**2.25**	**3.96**

Exhibit 9 – BCA Results for Each Project

Bridge ID	7% Discount Rate	3% Discount Rate
470035	0.87	1.45
470036	1.00	1.62
650010	0.83	1.69
650015	1.36	2.56
650049	3.66	6.19
650063	0.92	1.54
60006	2.22	3.77
60014	1.12	2.01
60040	1.03	1.76
60069	0.79	1.43
60135	0.91	1.61
60159	0.65	1.22
730005	1.99	3.64
730171	1.64	2.62
300036	3.30	5.97
300045	2.94	5.05
300082	7.56	14.22
300325	4.49	7.56
810009	20.93	34.78
810018	4.94	8.13
810133	5.12	8.06
810152	3.14	4.96
810195	3.88	6.38
810214	3.29	5.24
320011	1.10	2.90
320022	3.65	6.46
320054	0.32	0.67
320064	1.06	1.87
320087	4.76	8.10
410093	1.03	1.98
630041	0.62	1.24
630224	0.16	0.48
950093	3.96	6.22
950096	2.22	4.26
950117	7.66	13.75
950264	3.16	4.99
970037	1.74	2.85
970047	0.15	3.75
970091	1.88	2.99
970092	1.72	2.90
970096	1.87	3.05

Bridge ID	7% Discount Rate	3% Discount Rate
970105	1.28	2.12
20035	0.31	0.55
20133	0.77	1.46
960075	1.74	2.76
960419	1.89	2.97
960733	2.18	3.40
980020	0.88	1.51
980028	0.36	0.63
980059	1.02	1.83
980105	5.51	9.48
10291	1.00	1.64
960004	1.82	2.97
980080	3.03	5.42
480131	1.12	1.81
480212	0.55	1.32
480219	0.12	0.77
480214	0.80	1.33
410115	0.57	1.01
630080	0.60	1.05
320003	0.90	1.80
320004	0.56	1.27
320035	0.38	0.71
730123	3.33	5.89
730109	0.84	1.60
60072	0.55	1.01
810178	2.45	3.93
810348	6.66	10.54
650052	0.77	1.30
650093	1.40	2.28
960663	0.53	1.01
960667	0.71	1.21
960166	0.57	1.01
980189	1.85	3.28
850318	2.96	5.16
480166	0.55	1.01
480165	0.60	1.08

As each rural bridge has independent utility, a separate BCA was developed for each bridge. The individual results go up to 20.93 at a 7 percent discount rate and 34.78 at a 3 percent rate. While some of the Match Bridges do not cross a 1.0 threshold at 7 percent, all but one of the Posted bridges at least cross a 1.0 BCA ratio at 3 percent—a high bar for rural low-volume bridges. Moreover, the bridges meet the BCA test as a group. The reason many bridges do not result in BCRs over 1.0 is primarily due to the high cost of the bridge replacement and the low AADT in rural areas, resulting in lower net benefits than would be the case if there were more traffic on the bridges.

Appendix A List of Supporting Documents

AAA, Your Driving Costs, 2017, http://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf

American Soybean Association, "The Hard Cost of Bad Infrastructure," from spring 2017 *American Soybean Magazine,* https://soygrowers.com/american-soybean-mag/hard-cost-bad-infrastructure/

BEA Rate of Depreciation, Service Lives, Declining-Balance Rates, and Hulten-Wykoff Categories, http://www.bea.gov/scb/account_articles/national/wlth2594/tableC.htm

Brian Whitacre, Roberto Gallardo, Sharon Strover, Broadband′s contribution to economic growth in rural areas: Moving towards a causal relationship, Telecommunications Policy, Volume 38, Issue 11, 2014, Pages 1011-1023, ISSN 0308-5961, https://doi.org/10.1016/j.telpol.2014.05.005. (http://www.sciencedirect.com/science/article/pii/S0308596114000949)

FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13, https://www.fhwa.dot.gov/policy/hcas/addendum.cfm

NCDOT, An Analysis of the Traffic Safety Effects of Bridge Replacement on North Carolina Highways, 2002

North Carolina Agricultural Statistics, 2012 Crop & Livestock Cash Receipts by County, https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat/Section06.pdf

USDOT 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2018.pdf

USDOT Benefit-Cost Analysis (BCA) Resource Guide, March 1, 2016, https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf

USDOT Bridge Preservation guide, Maintaining a State of Good Repair Using Cost Effective Investment Strategies, August 2011, page 2, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiv-8XR8cLLAhVV5WMKHYZ6Ap8QFggcMAA&url=http%3A%2F%2Fwww.fhwa.dot.gov%2Fbridge%2Fpreservation%2Fguide%2Fguide.pdf&usg=AFQjCNEf26d_7T9a9n7jxVGGtwyGvq2zQg&sig2=Z8jY2-M9fT0zre_vXvSplg&bvm=bv.116954456,d.cGc

USDOT, Federal Transit Administration, New and Small Starts Evaluation and Rating Process Final Policy Guidance, August 2013

White House Office of Management and Budget. Historical Tables, Table 10.1 – Gross Domestic Product and Deflators Used in the Historical Tables 1940-2021. https://www.whitehouse.gov/omb/budget/Historicals

BCA excel workbook